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NEWS

May, 1958

News From the Bureau of Reclamation

A. Research in Gravelly Soils

The Earth Laboratory has been doing considerable research on the characteristics of gravelly soils. Three phases of study have been reported. The first was a study of shear characteristics on gravelly sands and sandy gravels, using large size triaxial shear testing equipment shown in Fig. 1. The second was on permeability and settlement of sand and sand-gravel mixtures. The third, which is just recently completed, was on the subject of compaction characteristics of gravelly soils, and used large size equipment shown in Fig. 2. The studies have been reported in the following papers:

1. W. G. Holtz and H. J. Gibbs, "Triaxial Shear Tests on pervious Gravelly Soil," Proceedings ASCE, Journal Soil Mechanics and Foundation Division, January 1956.
2. C. W. Jones, "Permeability and Settlement of Laboratory Specimens of Sand and Sand-Gravel Mixtures," Proceedings ASTM Symposium on Permeability of Soils, STP No. 163, 1954.
3. W. G. Holtz and C. A. Lowitz, "Compaction Characteristics of Gravelly Soils," presented at the meeting of ASTM Committee D-18 in Mexico City, December 1957.

Each of these studies determined the effects of various gravel contents and degrees of compaction. The most recent study dealt with a wider range of soils which included cohesive fines and provided compaction data, using the large size compactor shown in Fig. 2. Such data furnished information of compaction characteristics which were previously controlled in structures by theoretical computations and assumptions based on small size tests for the minus No. 4 material. The data of this compaction study will also provide control information for further tests on shear and permeability of gravelly soils with cohesive fines.

B. Undisturbed Sampling of Soils

Another study in the Bureau of Reclamation laboratory is the investigation

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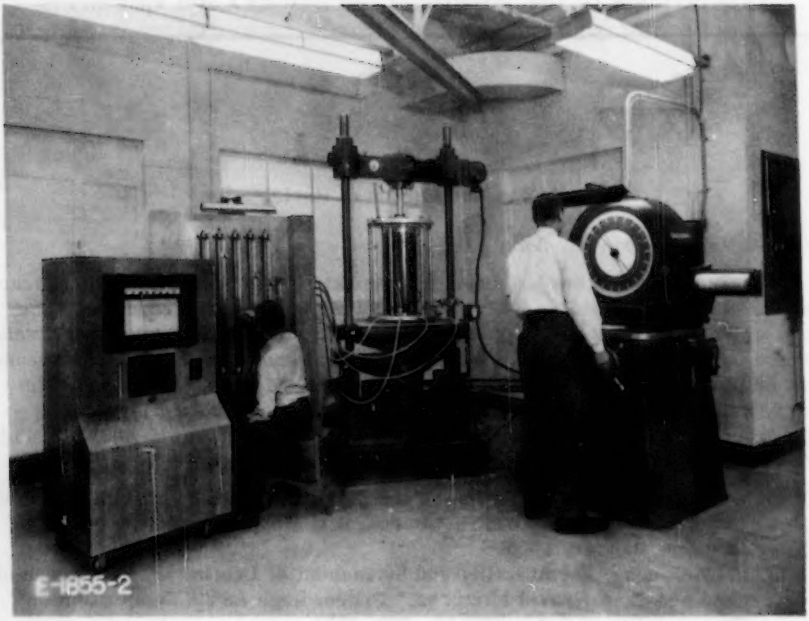

Figure 1--Large size triaxial testing apparatus for gravelly soils.

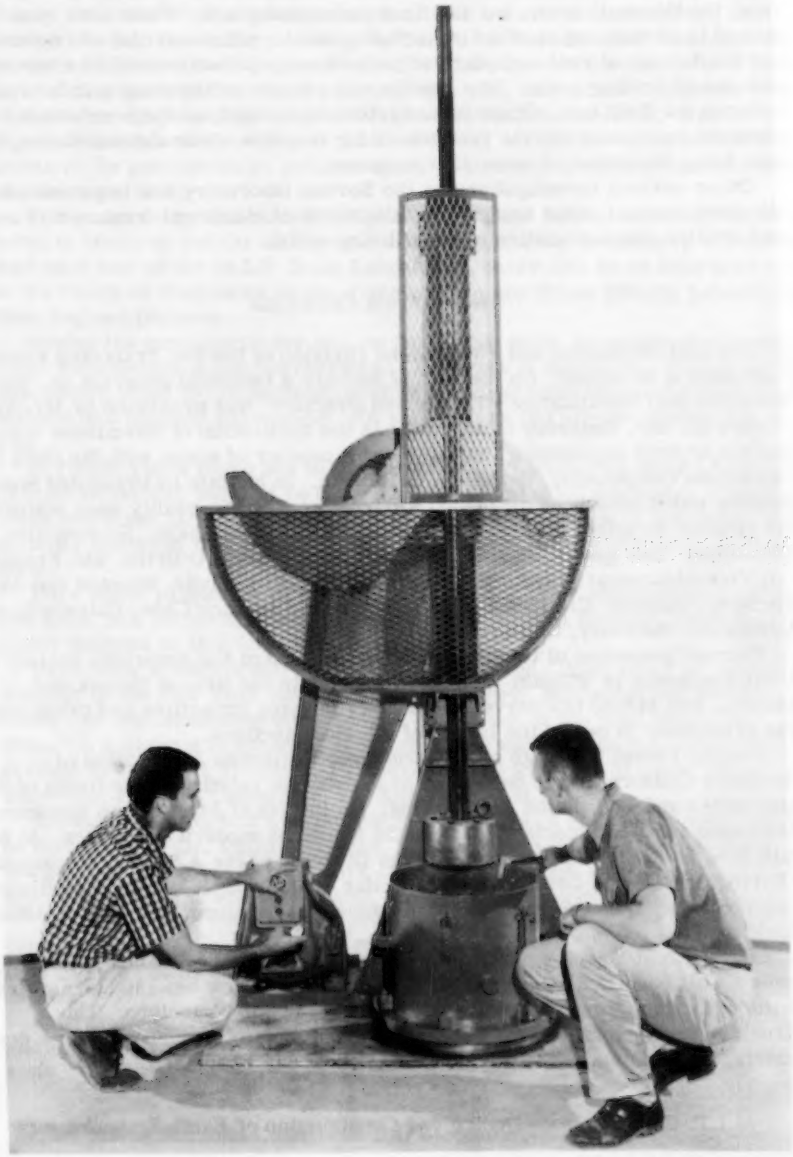

Figure 2--Large size compaction testing apparatus for gravelly soils.

of undisturbed sampling procedures and development of standards for Bureau use. Testing has involved trials of several samplers such as the double tube type, the thin wall drive, and the fixed piston samplers. Tests have been conducted in various types of soils, including sands, silts, and clays to determine the limitations of each sampler and procedure requirements in bit clearances and use of drilling muds. The results will permit establishing standard procedures for field use. Other investigation tools, such as the penetration resistance equipment and the vane tester for in-place shear determination, are also being investigated under this program.

Other current investigations by the Bureau laboratory are improvements of standard triaxial shear testing, investigations of electrical treatment of soils, and erosion characteristics of canal lining soils.

News From California

The Soil Mechanics and Foundations Division of the San Francisco section continues to be active. On the 27th of January a technical program on "Bituminous Soil Stabilization—Theory and Practice" was presented by Mr. Victor Endersby. Mr. Endersby is an expert in the application of bituminous materials to civil engineering, having spent a number of years with the Shell Development Corporation, Berkeley, California. In his talk he presented specifications which have been developed for treatment of low quality base material. An election to select officers for the coming years was held. Serving are: Chairman: Lee Lowry, Porter, Urquhart, McCreary & O'Brien, San Francisco; Vice-chairman: Raymond Lundgren, Woodward, Clyde, Sherard and Associates, Oakland, California, and; Secretary: Clarence Chan, University of California, Berkeley, California.

Current president of the San Francisco section of the American Society of Civil Engineers is William W. Moore, partner in the firm of Dames and Moore. Bill Moore has served the Society in many capacities and takes over the presidency of one of the larger of the local sections.

Several recent meetings of the Structural Engineers Association of Northern California have been devoted to subjects relating to the fields of Soil Mechanics and Foundation Engineering. On the 7th of January two speakers discussed various aspects of earthquake forces on modern structures. In his talk John E. Rinne, who currently is the Director of the A.S.C.E., discussed "Earthquake Design Criteria for Stack-like Structures". Mr. John A. Blume covered "Earthquake Shears and Resistance of Traditional and Modern Office Buildings".

On the 4th of March a panel of speakers discussed the planning, foundation design, soil conditions and structural design for the new headquarters office building for the Crown Zellerbach Corporation in San Francisco. This structure represents the first major office building to be supported on a deep mat-type foundation in the downtown section of San Francisco.

M.I.T. Conference on Design and Construction of Earth Embankments

This year M.I.T. will give a two-week summer Program on the design and construction of earth embankments. Scheduled for September 2-12, the Program is aimed at engineers who would like to review or learn more about the properties of fine grained soils as applied to embankment design and construction.

Taking part in the lectures and discussions will be the staff of the Soil Engineering Division at M.I.T. plus several guest lecturers. Compaction theory and the effects of placement conditions on soil properties will be covered in the introductory lecture by Dr. T. William Lambe, Associate Professor and Head of Soil Engineering. Next, Mr. Robert Philippe, Chief of the Special Engineering Branch, Corps of Engineers, will discuss methods of field compaction, emphasizing the practical considerations involved. Professor James Roberts and Mr. Charles Ladd of M.I.T. will follow up with considerations of the permeability, compressibility, strength and frost susceptibility of compacted soil.

The general organization of the course provides for the mornings to be devoted to lectures and the afternoons to discussions and laboratory visits. As well as a tour of the M.I.T. Soils Laboratory, there will be an afternoon visit to the Corps of Engineers Arctic Construction and Frost Effects Laboratory, New England Division.

Among the guest lecturers will be Dr. Harry Seed, Associate Professor of Civil Engineering at the University of California at Berkeley. Professor Seed will devote a day to the determination of required base course thickness for airfield and highway pavements. He will discuss the effects of repeated loading.

In recent years there has been considerable controversy as to whether ϕ or c or either one ought to be taken as zero in stability analyses. These concepts and other factors which enter into the determination of soil strength for stability analyses will be discussed by Professor Robert Whitman of the M.I.T. Staff.

Pore water pressures in compacted soils, and their measurement in lab and field, will be covered by Professors Whitman and Roberts, presenting the latest thoughts in this fast-developing area.

Particular attention will be given to earth dams. John Lowe III, Associate Partner in the New York form of Tippetts, Abbett, McCarthy and Stratton, will spend one day discussing their design; on the eve of the final day of the Program a banquet is planned, at which the Aswan Dam in Egypt will be described by Dr. Karl Terzaghi, Professor of the Practice of Civil Engineering, Emeritus, Harvard University, and Lecturer at M.I.T.

Embankments on soft foundations, and methods of stabilizing soft soils will be discussed by Dr. Philip Rutledge, partner of the firm of Moran, Proctor, Meuser and Rutledge, of New York City. Dr. Rutledge intends to elaborate specifically upon practical aspects, including the description of actual jobs.

The final major topic will be presented by Dr. Ralph Peck, Professor of Foundation Engineering at the University of Illinois. He will discuss field observations in connection with the stability of embankments and their foundations.

Engineers interested in attending the course should write for further information to the Office of Summer Sessions, M.I.T., Cambridge 39, Massachusetts.

United States National Council on Soil Mechanics and Foundation Engineering

The new chairman for the Executive Committee for 1958 is Dr. A. Casagrande. Professor Ralph B. Peck is Vice Chairman, and Mr. Willard J. Turnbull has been elected to the committee.

The Fifth International Conference will be held in Paris in July, 1961.

The Council has recently received a list of multilingual technical vocabularies published by the member organizations of the Union of International Engineering Organizations.

Another Report From the Fourth International Conference

At our request Professor G. A. Leonards, Purdue University has prepared the following summary of the papers and discussions presented at the Fourth International Conference on Soil Mechanics and Foundation Engineering, London, England in Division 1—"Soil Properties and Their Measurement":

In spite of a re-classification of topics, which was intended to distribute papers more equitably among the various Divisions, 46 papers were published in Division 1—Soil Properties and Their Measurement, and approximately 55 discussions were heard at the Conference. For the purpose of this review, it was decided to discuss briefly two important trends, and to confine the remainder of the review to considerations of the shearing resistance of soils.

Significant Trends

At the Centennial Meeting in Chicago, in September 1952, Professor Terzaghi (Terzaghi, 1953)* made an eloquent plea for the development and dissemination of data on the significant mechanical properties of sediments on a regional (or geologic) scale. Characteristically, he proceeded to show the way (Terzaghi, 1955), with his classic paper, "The Influence of Geological Factors on the Engineering Properties of Sediments". Although the General Reporter did not include geological and regional factors in his suggested discussions, it is pertinent to call attention to a number of notable contributions published in the Proceedings,—the Leda (or Laurentian) clay of the St. Lawrence and Ottawa Valleys (Eden and Crawford, pp. 22-27), the London clay (Skempton and Henkel, pp. 100-106), Canadian muskeg (or peat) (Radforth and MacFarland, pp. 93-97), modified Argentine loess (Bolognesi and Moretto, pp. 9-12), Negev loess (Kassiff, pp. 56-61), chalk (Meigh and Early, pp. 68-73), Indian "Black Cotton" soils (Mohan, pp. 74-76), and moraines (Bernell, Vol. II, pp. 286-295). In addition, the Division Journal recently published papers on loess (Clevenger, 1956); on the Mississippi Valley (Kolb and Shockley, 1957); and on "laterites" (Bawa, 1957). The growing awareness of the importance of this approach to the solution of foundation and earthwork engineering problems is reflected in the excellent papers presented to the Thursday morning session, which contributed significantly to our store of knowledge. However, the available data are still limited, and additional contributions of this nature are deserving of every possible encouragement.

It is difficult to summarize in a few statements the discussions on soil structure, but attention is directed to the gradual development of a better understanding of the physico-chemical properties of clays. Our ability to cope successfully with problems involving frost action, secondary consolidation, creep, long-term stability, arching, and—of course—chemical soil stabilization, is predicated upon a basic understanding of the clay-water-electrolyte system. Colloid chemistry and particle physics are tools that the soil mechanist should have in his kit, if steady progress is to be made toward the solution of these problems.

Shearing Resistance of Soils

It has often been emphasized that a major weakness in our methods of effecting stability analyses is the lack of a full understanding of the shearing resistance of soils (cf. Leonards, 1955). Nevertheless, it is felt that the magnitude of the errors involved in conventional practice has not been widely recognized. It is the writer's opinion that the attention focused on this problem was one of the major accomplishments of the 4th International Conference. Accordingly, the remainder of this discussion will be concerned with a review of the contribution to our knowledge of the shearing resistance of soils. For convenience, cohesionless and cohesive soils will be treated separately.

Cohesionless Soils

Three papers (Jakobson, pp. 167-171; Kirkpatrick, pp. 172-178; and Peltier, pp. 179-182) reported on the shearing resistance of sands. Jakobson used the Kjellman apparatus (Kjellman, 1936), which is capable of varying the three principal stresses independently, and found the influence of intermediate principal stress (δ_2) on the angle of internal friction to be as high as 15 degrees. As a variation in angle of internal friction of 15 degrees changes the bearing capacity factor approximately ten-fold, the significance of this phenomenon becomes readily apparent. Kirkpatrick used both conventional triaxial compression and extension tests ($\sigma_1 > \sigma_2 = \sigma_3$ and $\sigma_1 = \sigma_2 > \sigma_3$ respectively), and thick-cylinder tests. In the latter tests a range of values for the intermediate principal stress could conveniently be obtained. Kirkpatrick concluded that the effect of σ_2 was too small to be of practical importance. Peltier also performed axial compression and extension tests; in addition, he used a shear box in which σ_2 could be varied independently. Peltier found that the effect of σ_2 produced a difference in the angle of internal friction of the order of 7 degrees. Although the General Reporter invited discussion in explanation of these discrepancies, none was forthcoming. Perhaps the use of appropriate energy corrections (Bishop, 1950), would partially resolve these discrepancies.

Jacobson also studied the effect of shearing stresses on the value of Poisson's ratio (μ) and Young's modulus (E). Fig. 1 is taken from his paper. It will be noted that the effects of shear stresses are so large that their influence on E had to be plotted on a logarithmic scale. If these data are correct, the use of elastic theory (e.g. in the computation of pressure distribution) would appear to involve larger errors than has heretofore been contemplated. Variations in values of Poisson's ratio from less than 0.2 to greater than 0.6 were also reported.

A highly condensed paper by Whitman (pp. 207-210), summarizing the studies at the Massachusetts Institute of Technology on the behavior of soils under transient loadings, contains some interesting relationships, principally relating to sands. The data are too brief to permit adequate discussion, and it is hoped that they will soon be made available in much greater detail.

The difficulties being experienced with the interpretation of laboratory test data are similar to those being experienced in field determinations. A significant contribution to the latter problem was reported by Gibbs and Holtz (pp. 35-39). As this paper more properly belongs in Division 2, it will not be discussed here. However, in the writer's opinion, these difficulties reflect an inadequate understanding of the basic factors that influence the mechanical

properties of granular soils. Is it possible that the significance of "relative density" has been overemphasized? Our inability to explain the occurrence of flow slides in granular soils, and the absence of rational methods for estimating settlements due to vibrations—entirely apart from considerations of resonance—appears to support the view that a satisfactory unifying concept is not available. A critical study of the relative density concept, preferably in terms of the soil structure, is strongly indicated.

Cohesive Soils

Some of the sharpest differences of opinion expressed at the conference concerned the shear strength parameters applicable to a given problem involving cohesive soils. Misunderstanding which may be attributed to inconsistent definitions of soil mechanics terms has attained such proportions, that the International Society has appointed a special committee to resolve the problem. (Prof. R. E. Fadum is our representative on this committee.) Accordingly, before proceeding with the present discussion, the terms and symbols used will be defined (Fig. 2).

The undrained shearing resistance (one half the deviator stress at failure in undrained cylindrical compression tests, or the shearing resistance computed from vane tests) is designated c; the effective stress parameters are designated c' and ϕ', and the Hvorslev parameters c_t and ϕ_t, respectively. The value of c_t shown in Fig. 2 carries the subscript AB to emphasize the fact that it corresponds to a particular void ratio at failure ($^{ef}_{AB}$).

In a provocative paper, P. W. Rowe (pp. 189-192) presented a considerable body of circumstantial evidence which strongly suggests that at equilibrium, normally consolidated clays behave (at least approximately) as though $c_t = 0$. Rowe offers an explanation for this phenomenon in terms of the soil structure. Space limitations preclude a discussion of his concept here, but it is worth noting that Goldstein and Ter-stepanian (Vol. II, pp. 311-314) suggest a similar structure in explaining the long-term strength of clays and the creep of clay slopes. Perhaps the most telling evidence in favor of Rowe's hypothesis is the substantial agreement obtained (for the first time) between measured values of the coefficient of lateral earth pressure "at rest" and the corresponding values computed from shear strength parameters obtained by means of laboratory tests. Rowe's hypothesis has considerable bearing on the computation of "active earth pressures ultimately developed by clay soils against retaining walls and tunnels. The applicability of the "neutral earth pressure theory" (Tschebotarioff, 1951) in the solution of such problems appears deserving of more attention than it has been accorded in the past.

Skempton and Delory (Vol. II, pp. 378-381) present comprehensive data on the stability of natural slopes in the over-consolidated, fissured London clay. It is shown that the stable natural slope can be predicted only on the basis of systematically assuming $c' = 0$. These results are complemented by the analysis of two long-term failures in cuttings described by Henkel (Vol. II, pp. 315-320). On the other hand, recent studies of clay shales in Canada (Hardy, 1957), associates such failures with excess seepage pressures. Further studies are needed, but the evidence indicates that a preliminary analysis of the effects of softening in stiff, fissured clays can be made by assuming $c' = 0$.

For some years, it has been generally agreed that the end of construction stability of clay slopes could be analyzed satisfactorily using either c_u or $c' - \phi'$ parameters. Peterson et al. (Vol. II, pp. 348-352) present an analysis

of two embankments founded on highly plastic clay where the use of both types of shear strength parameters yielded too high a factor of safety (approx. 1.4) as no less than 13 slides developed during a period of from 4 months to 7 years after construction. It is possible that this discrepancy can be explained in terms of the reduced stability resulting from arching as suggested by Trollope (Vol. II, pp. 382-386). In his stimulating paper, Trollope directs attention to the less favorable distribution of normal and shear stresses that develops along a potential slip surface due to arching in the embankment, resulting in lower factors of safety than those which would be computed from conventional methods of analysis. The desirability of using higher factors of safety in embankment design, whenever considerable foundation settlements are anticipated, should be given proper attention in all future analyses.

It is regretted that space limitations do not permit a discussion of partly saturated (compacted) clays; however, it is clear that our understanding of the shearing resistance of soils is still far from adequate, and that comprehensive studies—both basic and applied—are urgently needed.

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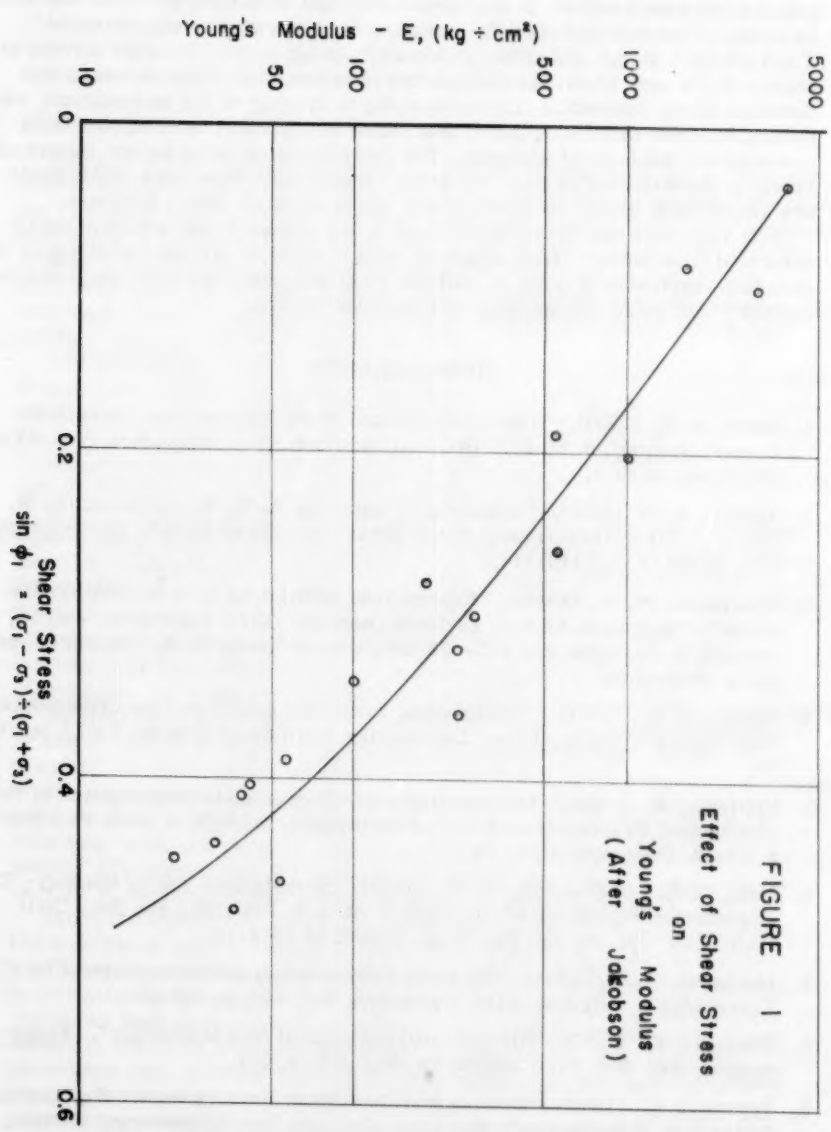

FIGURE 1
Effect of Shear Stress on Young's Modulus (After Jakobson)

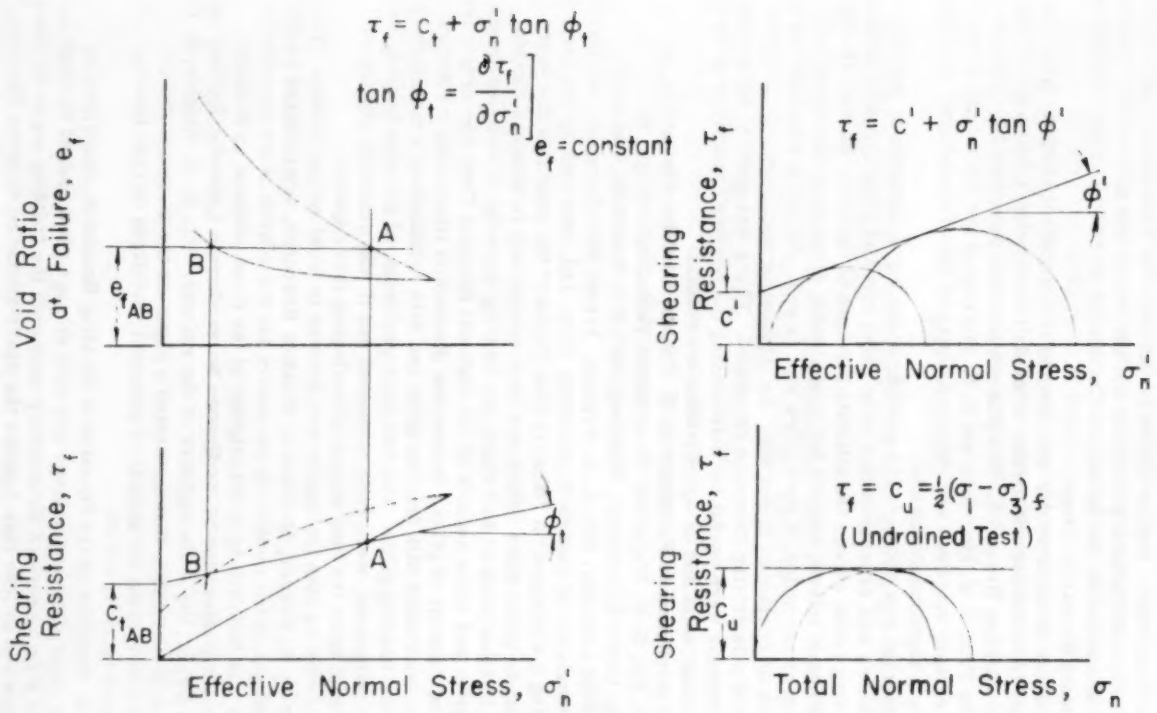

Figure 2
Definition of Shear Strength Parameters.

The Eleventh Canadian Soil Mechanics Conference

Pile Foundations and Frost Action were featured at the 11th Canadian Soil Mechanics Conference, held in Ottawa on 9th and 10th December. More than 200 engineers, contractors, geologists and soil scientists attended the meeting which was sponsored by the Associate Committee on Soil and Snow Mechanics of the National Research Council.

The program of the first day was devoted to the subject of the bearing capacity of pile foundations and a visit to the Soil Mechanics Laboratory of the Division of Building Research. The pile session was introduced by a paper prepared by Prof. I. F. Morrison and S. R. Sinclair of the University of Alberta. The paper reviewed was "Some Aspects of Pile Foundations" and was followed by a vigorous discussion.

Much interest was shown in the specifications for acceptance of wooden piles. Concern was expressed that when using crooked piles dynamic stresses during driving could exceed the ultimate strength of the outer fibres. Design considerations of lateral support for long slender piles were discussed and the question of corrosion of steel piles was raised. Attention was directed to recent work on corrosion in Norway. An interesting argument, pro and con, on the use of pile driving formulae developed. There was general agreement that the formulae were useful for determining the bearing capacity of piles in clean, granular soils and as specification for refusal.

A panel consisting of Professor D. F. Coates, Carleton University, as moderator, Dr. G. G. Meyerhof, Nova Scotia Technical College, Mr. C. V. Antenbring, Cowin & Company, Winnipeg, Mr. E. I. Rubinsky, Raymond Concrete Pile Company, Mr. L. A. Fraikin, Franki Pile Company, and Mr. N. D. Lea, Foundation of Canada Engineering Corp. Ltd. then took up the subject.

Following a statement on "What is Pile Failure" the panelists discussed special cast-in-place piles (which are used extensively in Western Canada), the use of friction piles in soft clays, the bearing capacity of rammed-in-place concrete piles and some aspects of the National Building Code concerning the soil bearing capacity of piles. Subsequent discussion illustrated the design difficulties associated with friction piles and with establishing a satisfactory value for end bearing piles. The two main problems, of ultimate bearing capacity and settlement, were fully discussed and it was generally concluded that load tests were the best means of evaluating pile capacity.

The program on 10th December was devoted to frost action in soils. The first paper by E. Penner, Division of Building Research, summarized experimental findings on the conditions necessary for the growth of ice crystals in soil. This was followed by a description of the frost problem as it affects maintenance and operation of the Quebec North Shore & Labrador Railway by Mr. R. W. Pryer, the soils engineer of the railway. Mr. E. B. Wilkins, B. C. Department of Highways, then presented a paper on the design of flexible pavements considering the effects of seasonal variations in road bearing capacity caused by frost action.

Mr. J. J. Hamilton of the Division of Building Research, described an interesting case of severe damage to a cold storage plant caused by frost action. After 4 or 5 years of satisfactory operation the building began to heave at the centre and in less than 2 years the heave amounted to more than one foot. Temperature measurements showed that when the frost line penetrated to the footing level (and the level of fine-grained soil) the heaving became rapid. Corrective measures were explained and the plant is now back to its

original level. A practical mathematical analysis of the general problem of heat flow under cold storage plants was presented by Dr. D. C. Pearce of the Division of Building Research.

Discussion on Frost Action covered a wide range of subjects. Much interest was shown in the relationships of loss of bearing capacity of highways to changes in density and water content of the supporting soil. The application of chemical treatment was considered at length.

The proceedings of the Conference will include summaries of the papers presented and will appear in the Technical Memorandum series of the A.C.S.S.M. It will be available in the spring of 1958.

May Newsletter

Deadline date for arrival at this office of contributions for the August Newsletter: June 20, please.

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